Identification of mealybugs (Hemiptera: Pseudococcidae) on banana and plantain in Africa

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Banana and plantain are important sources of carbohydrate and small-scale farmer income in parts of Africa, and Banana Streak Virus (BSV) causes serious loss of yield in some areas. Mealybugs (Hemiptera: Pseudococcidae) have been implicated in the transmission of BSV in the region. The identity of the mealybug vector(s) is not known, and the methods involved in mealybug preparation for identification are not widely available in Africa. This paper provides methods of collection, preservation and preparation, information on mealybug morphology, and an identification key to adult females of 20 species and 14 genera of mealybugs that may be found on Musaceae in Africa. Brief notes are given on the species, most of which are also important pests on other crops.

Key words: Hemiptera, Pseudococcidae, identification, banana, plantain, virus transmission, Banana Streak Virus.

INTRODUCTION

Banana and plantain (Musaceae: *Musa* spp.) are the world's fourth most important commodity and are grown in more than 120 countries (Harper & Hull 1998), providing a significant source of carbohydrates for over 400 million people in tropical regions (Anon. 1992). In the humid forest and mid-altitude zones of sub-Saharan Africa, banana and plantain supply over 25 % of the carbohydrate requirement for about 70 million people (Anon. 1992). These crops are a major source of income for small-scale farmers; any loss attributable to insect damage can seriously affect the local economy (Matile-Ferrero & Williams 1996).

During the last 15 years, plantain and banana production has been intensified and new pests and diseases have arisen that cause significant yield losses (Wilson 1988). Banana Streak Virus (BSV; genus *Badnavirus*) is one of the most widely distributed viruses of *Musa* spp. (Lockhart 1994; Su *et al.* 1997) and can cause considerable yield loss, especially when bananas are affected at the early stages of growth. Jones & Lockhart (1993) reported up to 90 % loss of yield in 'Poyo' plants with severe BSV symptoms. In severely infected areas in Uganda, plantations suffer almost 100 % loss of saleable yield (Tushemereirwe *et al.* 1996).

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Both integrated and episomal forms of BSV can be transmitted to daughter plants during vegetative propagation from an infected host, but it is believed that only the episomal forms can be transmitted by a vector. The epidemiology of BSV is still unclear and identifying putative mealybug vectors will help in developing disease management strategies. Virus transmission by mealybugs has been little studied, but four species (*Dysmicoccus brevipes* (Cockerell), *Planococcus citri* (Risso), *Pseudococcus comstocki* (Kuwana) and *Saccharicoccus sacchari* (Cockerell)) have been reported transmitting BSV in transmission tests (Lockhart & Olszewski 1993; Su 1998, 2000; Kubiriba *et al.* 2001). However, *P. citri, P. comstocki* and *S. sacchari* are not found commonly on banana or plantain in the field in Africa. More virus transmission studies of mealybugs on Musaceae in Africa are needed.

Little has been published on the identification of mealybugs in Africa in recent years, apart from a key to the mealybug genera of South Africa by Millar (2002). Several mealybug species have been identified on *Musa* spp. in Africa (Matile-Ferrero & Williams 1996), but the methods involved in their preparation for identification are not widely available in the region. It is important to be able to identify the mealybug vectors of BSV in order to facilitate their control. This paper provides methods of collection, preservation and preparation, and an identification key to adult females of

20 species of mealybug in Africa that may be found on Musaceae. Many of the species discussed are also important pests on other crops; brief notes are provided on each species.

METHODS

Mealybug species on plantain mentioned in Matile-Ferrero & Williams (1996), and samples collected on Musaceae from Africa in The Natural History Museum, London, U.K. collection were listed. In addition, samples from Musaceae in Africa (mainly Uganda) were collected and identified for this study.

Collection of mealybugs

Most mealybugs avoid sunlight and occur on leaf undersides or in crevices, axils, under bark or leaf sheaths, or even on the roots (Watson & Chandler 2000), so plants need to be examined closely in good light. On banana and plantain, mealybugs are found under the pseudo-stem leaf sheaths, on the roots and sometimes in banana weevil tunnels in the pseudo-stem. Ants often attend the colonies to collect their honeydew, and sooty mould often grows on honeydew deposits on surfaces below the colony. To ensure collection of adult females, specimens of various sizes should be collected. Picking individual insects off the plant often damages them, so pieces of infested plant should be removed and placed in polythene bags or plastic containers with perforated lids and kept in a well-ventilated, shady, cool place for transport back to the laboratory. In the laboratory, the appearance of the mealybugs in life should be noted or recorded by macrophotography, using a dissection microscope and incident illumination. The appearance of the insects in life is lost once they are immersed in alcohol.

Preservation of mealybugs

Live mealybugs are soft and easily damaged with forceps, therefore small pieces of infested plant should be placed in a tube of 80 % ethanol to kill and preserve specimens of a variety of sizes. The collection data should be written in pencil on paper that is then inserted into the tube with the specimens. If possible, as soon as possible after killing, each tube of mealybugs should be stood in a bowl of recently boiled water for 15–20 minutes to speed fixation and denature enzymes that might otherwise turn the body contents black. Good fixation, and storage in ethanol for 1–3 weeks to partly dissolve the waxy covering and toughen the cuticle, makes it easier to produce good slide preparations (rather than preparation of specimens immediately after collection).

Selection of specimens for identification

Mealybug species are identified using minute details on the cuticle of the adult female (Fig. 1), because male mealybugs (which are winged) have not been widely studied. The best specimens to prepare for identification are young adult females with small bodies, as they contain few eggs and require less manipulation to clean out the body contents. Each adult female is larviform but possesses large legs, a vulva and usually has multilocular disc pores. Immature females have smaller legs than adults, and lack a vulva: there are often fewer antennal segments than in the adult, and sometimes fewer pairs of cerarii; also, immatures usually lack multilocular disc pores, so they cannot be identified using keys to the adult females.

Preparation of mealybugs for identification

Recipes of the reagents required for the preparation of slide-mounts of mealybugs are given in Table 1. The schedule used for preparation and storage of microscope slide mounts of adult female mealybugs for identification is given in Table 2. Specimens should be processed in solid glass cavity blocks with glass lids and must never be allowed to dry out, to avoid air becoming trapped in the body. Slide preparation should be carried out using a dissection microscope with a glass stage and transmitted light from below; samples should be heated in covered cavity blocks on a thermostatically controlled dri-block, or in test-tubes in a water bath.

RESULTS

Nineteen species of mealybug, belonging to 13 genera, are known from Musaceae (mainly banana and plantain) in Africa. Adult females of these species may be identified using the key below. Another genus and species, *Planococcoides njalensis* (Laing), is included in the key even though it has never been collected from Musaceae, because it is a highly polyphagous African species and a known virus vector (on cacao).

Users of the key may find the illustration of

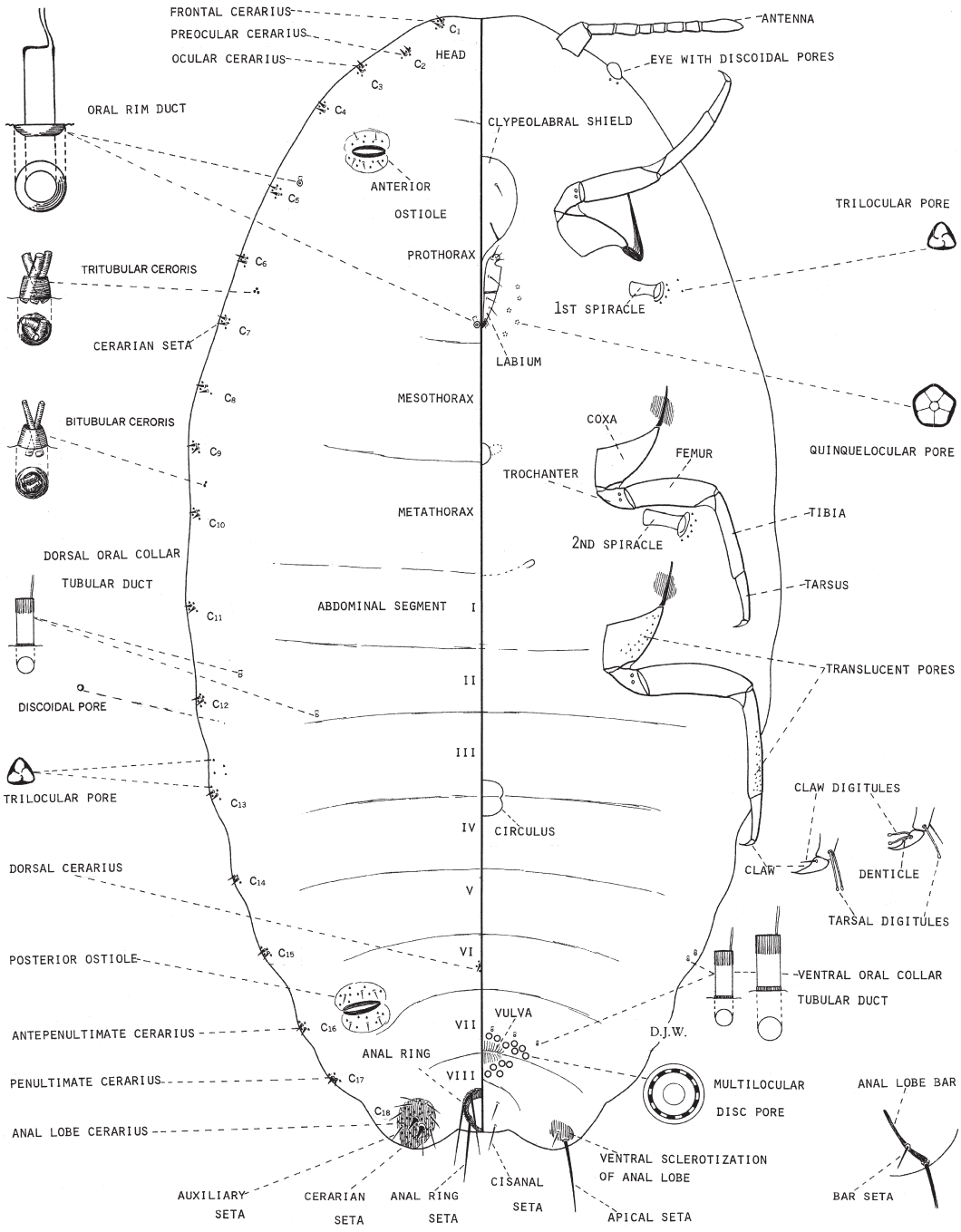

Fig. 1. Diagram showing general morphology of an adult female mealybug (after Williams (1985), © The Natural History Museum, London, U.K.).

Table 1. Recipes for reagents used in the preparation of microscope slide mounts of mealybugs, based on Watson & Chandler (2000). Many of these chemicals are toxic or flammable, so the bottles should be clearly labelled. They should be stored in a cool, dark place when not in use, and should never be left in direct sunlight.

Reagent	Function	Recipe and precautions
Acid fuchsin	Stains chitin and sclerotin red in acidic conditions; colourless in alkaline conditions	Mix 0.5 g Acid Fuchsin powder + 300 ml distilled water + 25 ml of bench hydrochloric acid; toxic, potential carcinogen
Canada balsam	Permanent mountant	Thin with xylene to an easy pouring consistency; flammable, toxic fumes
Carbol xylene	Dissolves fats and waxes	Mix equal volumes of phenol crystals and xylene at room temperature; corrosive, flammable, fumes toxic. See Histoclear phenol below for a safer alternative
Clove oil	Clearing agent; also dissolves fats and waxes	Purchase as anhydrous clove oil; should be pale honey-coloured and transparent; non-hazardous. Store in a brown bottle, as light causes deterioration
Distilled water	Rinses away ionic solutes	Distilled water, non-hazardous
Ethanol 80 %	Dehydrating agent; rinses out stain	For preservation and partial dehydration; toxic and flammable
Ethanol 100 %	Dehydrating agent; rinses out organic solvents	Use for complete dehydration; toxic and flammable
Glacial acetic acid	Acidifying and dehydrating agent	Concentrated acid; corrosive, fumes toxic
Histoclear phenol	Dissolves fats and waxes	Mix equal volumes of Histoclear and phenol crystals; corrosive, toxic fumes
Potassium hydroxide (KOH) 10 %	Macerating agent that hydrolyses proteins and emulsifies fats	Dissolve approximately 50 g potassium hydroxide pellets in 500 ml distilled water; corrosive alkali
Xylene	Organic solvent; dissolves fats and waxes	Solvent for thinning Canada balsam; can be used as a clearing agent; flammable, fumes toxic, potential carcinogen

mealybug general morphology (Fig. 1) and the explanatory notes on morphology in Table 3 helpful.

Key to the adult females of mealybug species on Musaceae in Africa

1. Anal lobes strongly projecting, heavily sclerotized, each tipped with a spine-like anal lobe seta (Fig. 2A); circuli numbering 2 or 3; eyes absent; venter of head bearing two large, thick setae. Feeding on roots . . . . . *Geococcus coffeae* Green
— Anal lobes only moderately developed, no more than partially sclerotized, each tipped with a long, slender anal lobe seta (Fig. 1); a single circulus present; eyes present; extra-thick setae absent from venter of head. Feeding sites various 2
2. Antennae each with nine segments 3
— Antennae each with 6–8 segments 6
3. Cerarian setae with truncate tips (Fig. 2Biv) . . . . . genus *Rastrococcus* . . 4
— Cerarian setae with sharply pointed tips . . . 5
4. Ventral multilocular disc pores present as far forward as thorax; dorsal setae beside anal ring much longer than on other segments; anterior ostioles present; circulus

Table 2. Schedule for preparation and storage of microscope slide mounts of mealybugs, based on Watson & Chandler (2000).

Step	Action
1	If possible, heat specimens in 80 % ethanol at about 70 °C for five minutes, to toughen the cuticle and dissolve some of the wax.
2	Under a dissection microscope, puncture the dorsum of the thorax of each specimen using the tip of a very sharp needle, without damaging any other parts of the body.
3	Use a micro-spatula to transfer specimens to 10 % potassium hydroxide (KOH) to macerate the body contents. Soak at room temperature for 24–48 hours, until each specimen becomes translucent but not completely colourless.
4	Using a mini-spatula, gently squash the body dorsoventrally to push the body contents (including eggs and fat droplets) out through the puncture in the thorax.
5	Rinse the specimens in distilled water for at least 10 minutes, with additional manipulation (if necessary) to expel any remaining body contents entirely. It is important at this stage to leave the body of each specimen as clean as possible and dorsoventrally flattened (as in Fig. 1). However, any remaining traces of wax will be dissolved later (stage 10).
6	Remove water using a pasteur pipette, and add several drops of glacial acetic acid and two drops of Acid Fuchsin stain. Cover and leave for several hours or overnight.
7	Remove stain and rinse with 100 % ethanol to remove surplus stain and fully dehydrate the specimens; soak for a few minutes. Do not manipulate specimens in alcohol because the cuticle becomes brittle when dehydrated and will be damaged.
8	Add a few drops of Histoclear phenol (or carbol xylene) to the dish and soak the specimens at room temperature until all fat/wax has dissolved. Very waxy specimens may require hours of soaking, or gentle heating, and several changes of dewaxing agent to remove all the wax.
9	Remove dewaxing agent and rinse specimens for 10 minutes in 100 % ethanol.
10	Remove alcohol and clear specimens in anhydrous clove oil for at least 10 minutes (can be left overnight). If clove oil is not available, xylene can be used instead but this tends to leave the specimens very brittle.
11	Label microscope slides before the specimens are placed on them, to avoid accidentally damaging the fresh mount; this also ensures the data are always associated with the specimens. The best labels are made of 0.3 mm thick, white card cut in 19 mm squares, glued onto the slides with wood glue, and are written in indelible, waterproof ink or pencil. The label on one end of the slide carries collection data (country, locality, host plant, any damage symptoms, collector's name, sample number, date of collection) and the other label carries the identification.
12	Place a small (2 mm diameter) spot of clove oil in the centre of each microscope slide, and transfer 1–3 specimens, one at a time, into the drop using thick mounted needles. Working under the dissection microscope, use fine mounted needles to arrange specimens.
13	Soak up the clove oil from the specimens using the corner of a folded tissue. Place a drop of a well-liquefied mountant (Canada balsam) 6–7 mm in diameter on the specimens and quickly spread it in a circular pool around them. Use the tip of a clean pin to lower a cover slip onto the mountant, and allow it to settle under its own weight.
14	Dry slide mounts in a horizontal position in a dust-free environment for three months at about 35 °C.
15	Store slide mounts horizontally in cool, clean, dark conditions away from moisture or any risk of attack by termites.

usually about seven times as wide as long . . . . . *Rastrococcus iceryoides* (Green)

— Ventral multilocular disc pores only present posterior to circulus; dorsal setae near anal ring approximately same length as those on other abdominal segments; anterior ostioles absent; circulus usually about five times as wide as long . . *Rastrococcus invadens* Williams

5. Oral rim tubular ducts present in several rows across dorsum of each segment; cerarii numbering 4–6 pairs, situated on posterior segments of abdomen; anal lobe bar present (not always well developed); quinquelocular pores absent . . *Maconellicoccus hirsutus* (Green)

— Oral rim tubular ducts absent; cerarii numbering 18 pairs, distributed around entire margin; anal lobe bar absent; quinquelocular pores numerous on venter . . . . . *Phenacoccus parvus* Morrison

6. Antennae each with six or seven segments . . 7

Table 3. Notes on some important morphological characters of adult female mealybugs, based on Watson & Chandler (2000).

Character	Comments
Antennae	Most mealybugs have 6–8 antennal segments (Fig. 1), but in a few genera there may be as many as nine or as few as two.
Legs	Minute, thin patches of cuticle called translucent pores may occur on the tibia and/or coxa (Fig. 1), more rarely on the femur and very rarely on the trochanter. They may be easier to see in reduced light levels or with phase contrast illumination. Translucent pores probably secrete sex pheromones.
Circulus	This is an area of thin cuticle overlying glandular tissue on the venter, usually between abdominal segments III and IV (Fig. 1). Some species do not have a circulus. The circulus varies in shape in different species, circular/quadrate/anvil- or dumbbell-shaped (Fig. 2C), or even conical. The circulus appears to be an adhesive organ, but in some species it may have some other function(s).
Cerarii	Each cerarius consists of two or more enlarged setae and several trilocular pores, situated on the body margin (Fig. 1). Sometimes several auxiliary filamentous setae are also present (Fig. 2E). The enlarged setae may be conical, lanceolate or truncate (Fig. 2B(ii–iv)). The basic number of cerarii is 18 pairs, but occasionally additional, intermediate cerarii are present between them. Some cerarii may be missing from the head or the thorax; in a few species, only the anal cerarii may be present. Cerarii often secrete and support marginal wax filaments in life.
Discoidal pores	The smallest body pores are discoidal pores, which are minute and of uncertain function; sometimes they are textured (*e.g.* in *Dysmicoccus brevipes*) or are larger on one surface than on the other.
Tubular ducts	Wax secreted by glands passes out through the cuticle via internal tubes called tubular ducts to form long wax filaments, *e.g.* to form the ovisac; so tubular ducts are most numerous in oviparous species. There are two main types: oral collar tubular ducts have a sclerotized collar within the orifice and lack any external rim (Fig. 1). Oral rim tubular ducts have a distinct external rim surrounding the orifice. The rim may be may be sclerotized, either flat (as in *Maconellicoccus*) or raised (as in *Pseudococcus,* Fig. 1); occasionally it may be difficult to see unless viewed in profile. The presence (as in *Ferrisia,* Fig. 2D) or absence of setae within the rim is an important character.
Ostioles	These are paired slits in the body wall, one pair being located on abdominal segment VI and the other on the prothorax (Fig. 1). Each ostiole has a muscular valve that can open or close, like a pair of lips. In most species of *Rastrococcus* the anterior pair of ostioles is absent. The probable role of ostioles is defence; when the mealybug is disturbed, they may open to exude a liquid that hardens in air, so any predator fouled by it is likely to have to clean itself, and may even starve if its mouthparts are clogged.
Setae	Body setae (as opposed to cerarian setae) are normally flagellate on the venter. Dorsal setae tend to be of one form characteristic of the genus – flagellate or lanceolate (as in *Phenacoccus*) or conical (Fig. 2B) , but occasionally there is more than one type present.

— Antennae each with eight segments 9

7. Antennae each with six segments; legs short and very robust, with tibia + tarsus shorter than trochanter + femur; cerarii present on head; anus situated more than 1.5 times its own length from apex of abdomen; anal lobe bar present . . . . . *Paraputo anomalus* (Newstead)

— Antennae each with seven segments; legs quite slender, with tibia + tarsus longer than trochanter + femur; cerarii absent from head (although single enlarged setae may be present); anus apical or situated no more than 0.5 times its length from apex of abdomen; anal lobe bar absent 8

8. Cerarii numbering 4–7 pairs, situated on posterior abdominal segments; circulus small and oval, situated within the bound-

aries of abdominal segment 3; dorsal setae conical; multilocular disc pores only present posterior to circulus; minute thick-rimmed pores absent from around base of hind coxa . . . . . *Nipaecoccus nipae* (Maskell)

— A single pair of cerarii present, situated on anal lobes (sometimes difficult to see); circulus very large and dumbbell-shaped (Fig. 2C), situated at the boundary between abdominal segments III and IV; dorsal setae robust flagellate; multilocular disc pores present dorsally and ventrally on all segments; minute thick-rimmed pores present on cuticle around base of hind coxa . . . . . *Saccharicoccus sacchari* (Cockerell)

9. Large oral rim ducts present on dorsum, each duct with several setae located within sclerotized rim (Fig. 2D) . . . . . *Ferrisia virgata* (Cockerell)

— Oral rim ducts, if present, each without any setae located within rim 10

10. Cerarii forming an almost continuous marginal band, due to presence of numerous intermediate cerarii; dorsal setae each with a curved tip; anal lobe cerarii each containing three or more cerarian setae, and venter of anal lobe widely sclerotized . . *Cataenococcus ensete* Williams & Matile-Ferrero

— Cerarii distinct, numbering 17 or 18 pairs; dorsal setae not strongly curved at tips; if anal lobe with more than two cerarian setae, then venter of lobe with an anal lobe bar present 11

11. Cerarii numbering 18 pairs (with three pairs present anterior to the eyes); slender anal lobe bar present 12

— Cerarii numbering 17 pairs (with only two pairs anterior to the eyes); anal lobe with ventral sclerotization triangular or oval, or approximately bar-shaped 15

12. Abdominal cerarii each containing three or more conical setae; legs short and very robust, with tibia + tarsus shorter than trochanter + femur; dorsal and ventral setae very long. Not recorded from Musaceae so far . . . . . *Planococcoides njalensis* (Laing)

— Abdominal cerarii each containing only two conical setae; legs moderately robust or slender, each with tibia + tarsus usually as long as or longer than trochanter + femur; dorsal setae short . . . . genus *Planococcus* . . 13

13. Circulus small, not as wide as length of hind trochanter. Discoidal pores each much larger than a trilocular pore, present in ventral median group between anal lobes, and associated with each eye. Oral collar tubular ducts absent from head and thorax . . *Planococcus musae* Matile-Ferrero & Williams

— Circulus larger, wider than length of hind trochanter. Discoidal pores each only slightly larger than a trilocular pore, absent from between anal lobes and only occasionally present near eye. At least a few oral collar tubular ducts present on head and thorax. These specimens are best identified to species by an expert 14

14. Oral collar tubular ducts present on margins of head and thorax; small group of discoidal pores present on dorsal midline of anterior abdominal and thoracic segments; hind femur rarely with translucent pores; cerarii on head and thorax containing conical setae almost as robust as those on abdomen; multilocular disc pores on cuticle posterior to front coxae usually few or absent . . . . . *Planococcus citri* (Risso)

— Oral collar tubular ducts absent from margins of thorax, and numbering only 0–4 on head; discoidal pores never forming groups on midline of abdominal or thoracic segments; hind femur sometimes with translucent pores present distally; cerarii on head and thorax containing conical setae much more slender than those on abdomen; multilocular disc pores present on cuticle posterior to front coxae often numbering more than five . . . . . *Planococcus ficus* (Signoret)

15. Oral rim tubular ducts present on dorsum (most often on head and beside abdominal cerarii) 16

— Oral rim tubular ducts absent from dorsum . . . . . genus *Dysmicoccus* . .19

16. Anal lobe bar present; cerarii each without any auxiliary (flagellate) setae; hind femur without any translucent pores . . . . . *Paracoccus burnerae* (Brain)

— Ventral sclerotization of anal lobe oval or triangular; cerarii each containing flagellate auxiliary setae (Fig. 2E); hind femur always with translucent pores present 17

17. Most cerarii each associated with two or three dorsal oral rim tubular ducts; penultimate and anal lobe cerarii each situated on a large sclerotized area, other cerarii situated

on membranous bases; multilocular disc pores present only immediately next to vulva
. . . *Pseudococcus longispinus* (Targioni Tozzetti)
— Cerarii each associated with no more than one dorsal oral rim tubular duct; if penultimate cerarius situated on a sclerotized area, then so are all other cerarii; multilocular disc pores present at least as far forward as circulus 18
18. Cerarii all situated on bases sclerotized to some degree; multilocular disc pores present only posterior to circulus; dorsal oral rim ducts numbering fewer than seven, never present on midline of posterior abdominal segments
. . . . . *Pseudococcus cryptus* Hempel
— Only anal lobe cerarii situated on sclerotized bases; multilocular disc pores present on thorax as well as abdomen; dorsal oral rim ducts numbering more than seven, some present on midline of some posterior abdominal segments
. . . . . *Pseudococcus comstocki* (Kuwana)
19. Discoidal pores associated with each eye (Fig. 1); dorsum of abdominal segment VIII (just anterior to anal ring) with setae much longer than on preceding segments, and with numerous discoidal pores, each larger than a trilocular pore
. . . . . *Dysmicoccus brevipes* (Cockerell)
— Without any discoidal pores by eye; dorsum of abdominal segment VIII with setae not significantly longer than those on preceding segments; any discoidal pores present on segment VIII each not larger than a trilocular pore . . . *Dysmicoccus grassii* (Leonardi)

Notes on the mealybug species

Cataenococcus ensete Williams & Matile-Ferrero is a morphologically variable species that was described by Williams & Matile-Ferrero (2000) on *Ensete ventriculosum* from Ethiopia. The species was found on plants infected with Ensete Streak Virus, a badnavirus that is thought likely to be related to BSV and Sugarcane Streak Virus. There is no direct evidence yet that this mealybug species transmits the virus. It has not been recorded from any other host plant. Williams & Matile-Ferrero (2000) illustrated *C. ensete* and discussed its separation from other species of *Cataenococcus.*

Dysmicoccus brevipes (Cockerell) is a polyphagous and tropicopolitan species that is common and widespread throughout Africa (Ben-Dov 1994; Matile-Ferrero & Williams 1996). It occurs on both aerial and subterranean parts of its host plants, and shows a preference for sweetness, often causing problems on pineapple, fruit trees and sugarcane (Watson & Chandler 2000). *D. brevipes* was recorded on plantain and *Musa* sp. from Eritrea, Ghana, Nigeria, Sierra Leone and Uganda by Williams & Matile-Ferrero (2000). It was also found on banana from Uganda in this study; most of these samples were collected from plants showing Banana Streak Virus symptoms. The species was illustrated and discussed by Williams & Watson (1988) and Williams & Granara de Willink (1992). In transmission tests, Su (2000) successfully demonstrated transmission of BSV by *D. brevipes.*

Dysmicoccus grassii (Leonardi) (synonym *D. alazon* Williams) is a fairly polyphagous mealybug originating from Central and South America, which often feeds on fruit trees, beverage crops and vegetables. It is injurious to bananas in the Canary Islands, where heavy infestations of the axis and fruit bunches causes premature ripening and reduced productivity. The species was recorded from Nigeria by Matile-Ferrero & Williams (1996) on false horn plantain, on the pseudostem under the dead leaf sheaths; some of the host plants were dying of viral infection. The species was illustrated and discussed (as *D. alazon*) by Williams & Granara de Willink (1992). There is a risk that this damaging mealybug may spread to other parts of sub-Saharan Africa.

Ferrisia virgata (Cockerell) is one of the commonest, most tropicopolitan mealybug species and is widespread in most of Africa; it is highly polyphagous, occurring on aerial parts of mainly woody hosts. The species is quite distinctive in life, with two long, white wax pencils at the posterior end and paired dark grey, longitudinal streaks on the dorsum (Watson *et al.* 1995 provided a photograph). It was recorded on *Musa paradisiaca* from Ghana by Williams & Matile-Ferrero (2000). Williams & Watson (1988) illustrated *F. virgata* and the similar species *F. malvastra* McDaniel (under the synonym *F. consobrina* Williams & Watson). *F. malvastra* has been recorded from Ghana, Somalia and Sudan, but there is no record of it feeding on Musaceae so far. Williams (1996) provided a key to all the known species of *Ferrisia.*

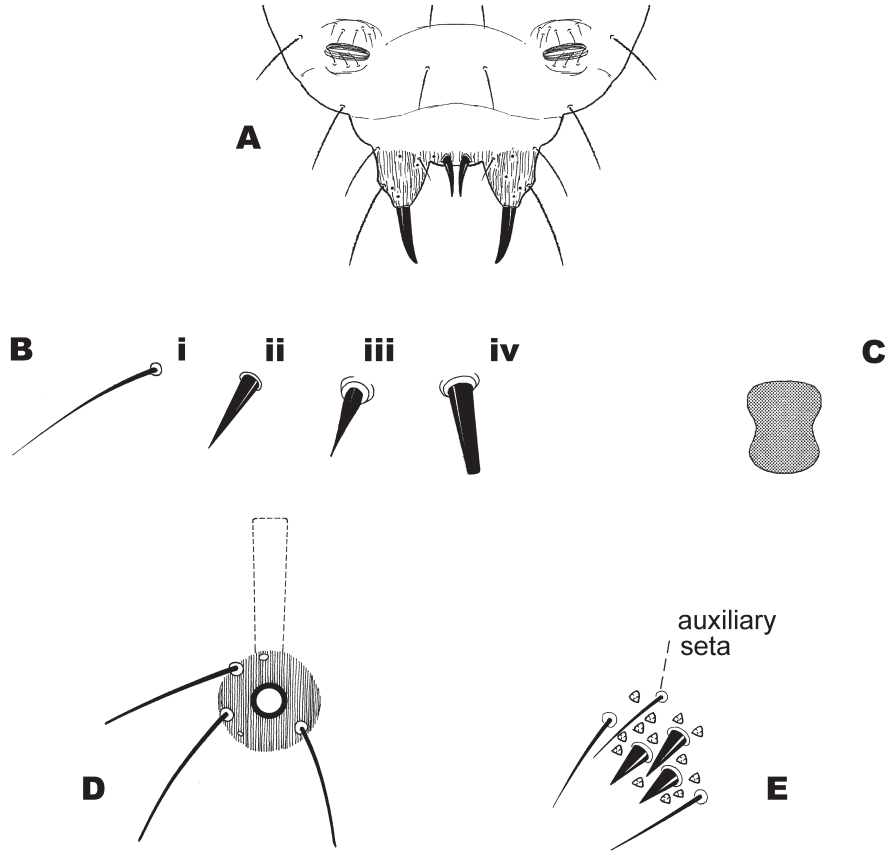

Fig. 2. Diagrams of some morphological features characteristic of adult females of certain genera of mealybugs. **A**, projecting anal lobes with spine-like anal lobe setae, typical of *Geococcus*; **B**, shapes of setae: i = flagellate, ii = conical, iii = lanceolate, iv = truncate; **C**, dumbbell-shaped circulus of *Saccharicoccus sacchari*; **D**, large oral rim duct with several setae located within sclerotized rim, as found in *Ferrisia virgata*; **E**, cerarius containing auxiliary setae, as found in *Pseudococcus* species.

In transmission tests, Su (1998) could not demonstrate transmission of BSV by *F. virgata.*

Geococcus coffeae Green is a small, root-feeding mealybug with distinctive, prominent anal lobes and setae, giving it a pincer-like appearance at the posterior end (Fig. 2A). The species is polyphagous and has been recorded from the roots of beverage crops and fruit trees (including *Musa* sp.), vegetables (including sweet potato), tobacco and grapes. *G. coffeae* has been recorded from Ghana, Nigeria, Uganda, Kenya and Zanzibar (Ben-Dov 1994), but not on Musacaeae. It was illustrated and discussed by Williams (1958), Williams & Watson (1988) and Williams & Granara de Willink (1992).

Maconellicoccus hirsutus (Green) is a highly polyphagous, damaging mealybug that originated in southern Asia. Since the early 1990s it has spread to the Caribbean, Central and northern South America, California, Florida, Hawaii, Tonga, Tuvalu, Vanuatu and Samoa, causing concern. The saliva of this insect causes severe stunting and distortion of young growth, defoliation and even plant death in sensitive host plants (e.g. species of *Albizia, Pithecellobium* and *Hibiscus*). Some workers have attributed this damage to transmitted viruses (on cacao in Zanzibar (De Lotto 1967a) and on mulberry in India (Tewari *et al.* 1994)), but no evidence of virus transmission has been found. Members of the genus *Hibiscus* are favourite hosts; Musaceae are not, but *M. hirsutus* has been recorded feeding on *Musa* sp. In Africa this mealybug has been recorded from Benin, Burkina Faso, Cameroon, Central African Republic, Chad, Gabon, Ivory Coast, Kenya, Liberia, Niger, Nigeria, Senegal, Somalia, Sudan, Tanzania and Democratic Republic of Congo (DR Congo) and it has

been intercepted from Zambia at Chicago, U.S.A. (Williams 1996), but never on Musaceae. *Maconellicoccus hirsutus* was illustrated and discussed by Williams (1996a), and characters distinguishing it from *M. ugandae* (known from Cameroon, Ghana, Sudan and Uganda) were given by Williams (1986).

Nipaecoccus nipae (Maskell) is a mealybug native to the Neotropical Region that feeds on fruit trees (especially guava) and palms. In life, it is a small species that feeds on leaf undersides and develops a quilt-like pattern of white or buff wax cushions on the dorsum. It has been recorded from South Africa, Tanzania (including Zanzibar), Zimbabwe and Madagascar on palms but not Musaceae; however, it has been recorded feeding on *Musa* sp. elsewhere (Ben-Dov 1994). The species is actively extending its range, and has recently been recorded from Java, and in the Pacific islands from Samoa and Pohnpei. Williams & Granara de Willink (1992) illustrated and discussed *N. nipae.*

Paracoccus burnerae (Brain) is a fairly polyphagous species that is native to South Africa, where it is one of the three most important species on citrus (Hattingh 1993); it has also been recorded from Kenya, Angola, Zimbabwe and DR Congo on a variety of hosts, including *Nerium oleander.* The species was recorded on *Ensete* sp. from Kenya by Ben-Dov (1994) and Williams & Matile-Ferrero (2000), and illustrated and discussed by De Lotto (1967); Ben-Dov (1994) summarized its taxonomy.

Paraputo anomalus (Newstead) (synonyms *P. ritchiei* Laing and *P. multispinosa* James) is a morphologically variable species with the anus situated dorsally. It was recorded on the roots of *Musa* sp. from Uganda by Williams & Matile-Ferrero (2000) and is also known to occur in Ghana, Kenya and Tanzania on the trunks of a variety of trees, sometimes under the bark and attended by ants. Ant-attended mealybugs are sometimes carried from one feeding site to another by attendant ants, either accidentally or deliberately. *Paraputo anomalus* was illustrated and discussed by Williams (1958).

Phenacoccus parvus Morrison is a fairly polyphagous, Neotropical mealybug that has been spreading through the Pacific islands, Australia and southern Asia over the last twenty years. It can be damaging to vegetables and herbaceous plants, especially Solanaceae, if its principal host (*Lantana camara*) is growing nearby (Marohasy 1994). The species has been collected from Gabon, Senegal and DR Congo (Williams & Granara de Willink 1992) but not on Musaceae; however, it has been recorded on *Musa* sp. from elsewhere (Ben-Dov 1994). Williams & Granara de Willink (1992) provided an illustration and discussion, and Watson *et al.* (1995) provided a photograph.

Planococcoides njalensis (Laing) is a highly polyphagous African species, known from Cameroon, Benin, Ghana, Guinea, Ivory Coast, Liberia, Nigeria, Principe, São Tomé, Sierra Leone, Togo, DR Congo and Ethiopia. It is the most important vector of Swollen Shoot Virus disease of cocoa (Strickland 1951a,b). There are no records of this species attacking Musaceae so far, but the species is included here because it may yet be found on these hosts. Ezzat & McConnell (1956) redescribed and illustrated *P. njalensis.*

Planococcus citri (Risso) is a highly polyphagous, cosmopolitan species of Old World origin; in Africa it is known to occur in Angola, Ivory Coast, Eritrea, Ethiopia, Ghana, Kenya, Malawi, Nigeria, Principe, São Tomé, Senegal, Sierra Leone, South Africa, Sudan, Swaziland, Tanzania (including Zanzibar), DR Congo, Zambia and Zimbabwe. It has been recorded on a wide variety of fruit, beverage and vegetable crops and ornamental plants, including Musaceae. *Planococcus citri* was recorded on *Musa paradisiaca* from Ghana by Williams & Matile-Ferrero (2000). In transmission tests, Su (1998) successfully demonstrated transmission of BSV by *P. citri.* The species was illustrated and discussed by Cox (1989); Watson *et al.* (1995) provided a photograph. This species is very difficult to separate from *P. minor* (Maskell) and *P. ficus* (Signoret), so expert identification is recommended. Specimens of *P.* ?*citri,* field collected on banana in Uganda by J. Kubiriba in April 2002, resembled *P. ficus* in having a few translucent pores towards the distal end of the hind femur. This might be due to environmental conditions such as high temperatures (Cox 1983), or it might indicate that the specimens are hybrids between *P. citri* and *P. ficus.*

Planococcus ficus (Signoret) is a fairly polyphagous species of Old World origin, possibly from the Middle East or the Indian subcontinent. In Africa, it has been recorded from Angola, Egypt, Ethiopia, Libya, South Africa and Sudan. It was recorded on *Ensete ventricosum* from Ethiopia by Williams & Matile-Ferrero (2000). The species was illustrated and discussed by Cox (1989), and is well known as a pest of grapes. It is very difficult to separate from *P. citri* and *P. minor* (Cox 1989

provided a key); expert identification of this species is recommended.

Planococcus musae Matile-Ferrero & Williams was described from Nigeria on false horn plantain showing symptoms of Banana Streak Virus. There was no evidence to show that this mealybug was the virus vector. The species has not been recorded from any other host plant. Matile-Ferrero & Williams (1996) illustrated *P. musae* and discussed its separation from other species of *Planococcus* known from Africa.

Pseudococcus comstocki (Kuwana) is a polyphagous species of Palaearctic origin. In Africa it has only been identified twice, once from Ghana (on Irish potato) and once, tentatively, from Kenya (on coffee); however, it has been recorded feeding on *Musa* sp. elsewhere (Ben-Dov 1994). This species is a serious pest of deciduous fruit trees in the eastern U.S.A. and Japan. Williams & Granara de Willink (1992) illustrated and discussed *P. comstocki* and how to distinguish it from the similar *P. cryptus* Hempel. In transmission tests, Su (2000) successfully demonstrated transmission of BSV by *P. comstocki* in Taiwan.

Pseudococcus cryptus Hempel (*P. citriculus* Green is a synonym) is a polyphagous species that is fairly widespread in the tropics. In Africa it has been recorded only from Tanzania (Zanzibar and possibly Dar es Salaam), on *Citrus* and *Cocos nucifera*; however, it has been recorded on *Musa* sp. elsewhere (Ben-Dov 1994). It is often found on citrus and palms, which it can damage. In life this species resembles *P. longispinus,* but the wax pencils are shorter and the posterior pair are divergent and always shorter than the body (Watson *et al.* 1995 provided a photograph). Williams & Granara de Willink (1992) illustrated and discussed *P. cryptus* and how to distinguish it from the similar *P. comstocki.*

Pseudococcus longispinus (Targioni Tozzetti) is a highly polyphagous, cosmopolitan species of Old World origin, which feeds on a wide variety of woody and herbaceous hosts including fruit trees, vegetable crops and ornamental plants. First instar *P. longispinus* on grapevines are vectors of Grapevine Leafroll-associated Closterovirus, GLRaV-3 (Peterson & Charles 1997; Tanne *et al.* 1989) and Grapevine Trichovirus A (GAV) (Notte *et al.* 1997). The species is also associated with pitting of grapevine stems (Rosciglione & Gugerli 1986) and is an important pest on this crop in European and Mediterranean countries, Australia and New Zealand. In Africa it has been recorded from Ghana, Kenya, Malawi, Nigeria, São Tomé, South Africa, Tanzania (including Zanzibar), Togo, DR Congo and Zimbabwe. There is no record of *P. longispinus* on Musaceae in Africa, but it has been recorded on *Musa sapientum* elsewhere (Ben-Dov 1994). In life, undisturbed mature females develop parallel white wax pencils at the posterior end that are up to three times as long as the body, and shorter pencils around the rest of the body margin. The species was illustrated and discussed in Williams & Watson (1988) and Williams & Granara de Willink (1992).

Rastrococcus iceryoides (Green) is a species native to southern Asia that has been long established on the east coast of Africa (Kenya, Tanzania, including Zanzibar) (Williams 1989). It spread inland during the early 1990s to the Tanzania/Malawi boarder, where it caused serious damage to mango until natural enemies were introduced to control it. In life, the species resembles rather small cottony cushion scale (*Icerya purchasi* Maskell, Hemiptera: Margarodidae). It is quite polyphagous and attacks the leaf mid-veins and flowers of fruit trees; it was recorded on *Musa* sp. from Tanzania (Zanzibar) by Williams & Matile-Ferrero (2000). Williams (1989) illustrated and discussed *R. iceryoides.*

Rastrococcus invadens Williams is native to southern Asia but was accidentally introduced to Ghana and Togo in 1981/82 and has since spread to Benin, Nigeria, Sierra Leone and DR Congo. Like *R. iceryoides,* it feeds along the leaf veins and attacks a wide range of fruit trees; it can be very damaging to mango (Williams 1989). In life, *R. invadens* develops very long, slender white wax pencils from the body margins; Williams (1989) provided a photograph, an illustration and discussion. *R. invadens* was recorded on *Musa* sp. and *M. paradisiaca* from DR Congo, Ghana and Togo by Williams & Matile-Ferrero (2000).

Saccharicoccus sacchari (Cockerell) is normally found feeding on aerial parts of sugarcane, although it has been recorded moving (with the aid of ants) to the stem just below the soil surface after harvest (Williams & Granara de Willink 1992). This species has not been collected from Musaceae in the field, but has been reported transmitting BSV between banana plants under screenhouse conditions (Lockhart & Olszewski 1993). It is known from Ghana, Angola, Namibia, South Africa, Zimbabwe, Malawi, Tanzania, Uganda, Kenya, Somalia,

Ethiopia, Sudan and Egypt. Williams (1970, 1985), Williams & Watson (1988) and Williams & Granara de Willink (1992) illustrated and discussed *S. sacchari.*

CONCLUSION

Mealybugs have been little studied as vectors of plant viruses, although there is evidence that they can be important vectors of virus diseases in plantation crops and vineyards. Studies are needed to identify the species responsible for transmission of important virus diseases, as once the vector's identity is known there may be good potential for vector control by host-specific natural enemies. Mealybugs have relatively host-specific hymenopteran parasitoids that have been used very successfully in classical biological control programmes, e.g. control of *Phenacoccus manihoti* on cassava across most of sub-Saharan Africa by the encrytid wasp *Apoanagyrus (Epidinocarsis) lopezi* de Santis (Zeddies *et al.* 2001), and of *Rastrococcus invadens* on mango and other fruit trees in West Africa by the encyrtid *Gyranusoidea tebygi* Noyes (Vögele *et al.* 1991).

Matile-Ferrero & Williams's (1996) paper on mealybugs on *Musa* spp. in Africa did not provide the methods involved in preparation of mealybugs for identification, and Millar's (2002) key to the mealybug genera of South Africa provided only an overview of the process. The present paper provides details of these methods, and means of identifying 20 economically important mealybug species in Africa. The identification of putative mealybug vectors of Banana Streak Virus and other virus diseases of plantation crops will help in developing sustainable disease management strategies in the region.

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